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Effect of Flammulina velutipes mushroom and soybean oil as a fat substitute on the quality of chicken sausage

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Low-fat meat products are the major trends in developing healthier meat products. Attention is drawn that the animal fat is essential for emulsified meat products to enhance the stability, flavor, cooking yield, and texture. The low energy density and healthier ingredients can replace some or all of the fat in emulsified meat products according to some studies. As can be noted that compound fat substitutes, such as vegetable protein and carrageenan, vegetable oil and vegetable fibre, cellulose, and water, improved texture better than single fat substitutes. Nevertheless, the character of the emulsified meat product will eventually decrease as the amount of animal fat is reduced. Therewith, a little information is available about using Flammulina velutipes and soybean oil as fat alternatives in the manufacture of chicken meat products. The chicken sausage was used as the research object, and Flammulina velutipes and soybean oil were used as fat substitutes to study their effects on the quality of the chicken sausage. Chicken meat, salt and sodium polyphosphate were used for preparation of the sausages. Firstly, the mushroom and soybean oil were mixed in a ratio of 1:1.5, replacing the fats of 25 %, 50 %, 75 % and 100 % respectively. Then, cooking yield, folding test, pH, color, and sensory evaluation were measured. The experimental results showed that when adding Flammulina velutipes and soybean oil, the cooking yield, pH, L and b* value were increased; folding test values for the 75 % and 100 % experimental groups decreased; chicken sausage with 50% fat replacement had the highest sensory score. In summary, replacing 50% of the fat in chicken sausage with Flammulina velutipes and soybean oil was optimal. The addition of Flammulina velutipes and soybean oil increased the brightness and yellowness of the chicken sausages. The low addition of Flammulina velutipes and soybean oil decreased the redness of the sausage, which increased when Flammulina velutipes and soybean oil completely replaced the fat Flammulina velutipes and soybean oil compound is a promising fat substitute in the development of low-fat meat products.*

Key words: *Flammulina velutipes mushroom, meat, soybean oil, fat substitute, chicken sausage, quality.*

Вплив гриба Flammulina velutipes та соєвої олії як замінників жиру на якість курячих сосисок

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М'ясні продукти з низьким вмістом жиру є основними трендами під час розробки м'ясних продуктів для здорового харчування. Слід звернути увагу на те, що тваринний жир необхідний для емульгованих м'ясних продуктів для підвищення стабільності, смаку, виходу та покращення текстури. Згідно з деякими дослідженнями, сировина з низькою енергетичною цінністю та більш корисні інгредієнти можуть замінити частину або весь жир у емульгованих м'ясних продуктах. Варто зазначити, що такі замінники жиру, як рослинний білок і карагенан, рослинна олія і рослинна клітковина, целюлоза і вода, досить суттєво покращують консистенцію готового продукту. Крім того, досить небагато інформації щодо використання Flammulina velutipes і соєвої олії як альтернативних замінників жиру при виробництві продуктів з курячого м'яса. Курячі сосиски були об'єктом дослідження, а

Flammulina velutipes і соєва олія використовувались як замінники жиру. Для приготування сосисок використовували куряче м'ясо, сіль і поліфосфат натрію. Було вивчено вплив цих компонентів на якісні показники курячих сосисок. Спочатку комбінували грибну сировину та соєву олії у співвідношенні 1:1,5, замінивши жири 25 %, 50 %, 75 % та 100 % відповідно. Потім вимірювали вихід, текстурні показники, pH, колір і сенсорні показники. Експериментальні результати показали, що при додаванні Flammulina velutipes і соєвої олії збільшувались вихід, значення pH, L і b*; значення текстурних показників для 75 % і 100 % експериментальних зразків знизилися; курячі сосиски з 50 % заміною жиру виявили найкращі сенсорні показники. Загалом, заміна 50 % жиру в курячих сосисиках на Flammulina velutipes і соєву олію була оптимальними. Додавання Flammulina velutipes і соєвої олії посилило яскравість і жовтизну курячих сосисок. Низьке додавання Flammulina velutipes і соєвої олії зменшило почервоніння ковбаси, яке посилилося, коли Flammulina velutipes і соєва олія повністю замінили жир. Flammulina velutipes і соєва олія є перспективним замінником жиру при розробці нежирних м'ясних продуктів.*

Ключові слова: *гриб Flammulina velutipes, м'ясо, соєва олія, заміна жиру, курячі сосиски, якість.*

Introduction

Meat and meat products are nutritious. Animal fat is essential for emulsified meat products to enhance the stability, flavor, cooking yield, and texture (De Carvalho et al., 2020). Nevertheless, animal fat has significant energy value and is potentially harmful to human health (Varga-Visi & Toxanbayeva, 2017; Kaynakci & Kili, 2021). One of the major trends in developing healthier meat products is low-fat meat products (Kumar, 2019). However, the character of the emulsified meat product will eventually decrease as the amount of animal fat is reduced (Zhang et al., 2022).

According to some studies, low energy density and healthier ingredients can replace some or all of the fat in emulsified meat products, such as soy protein, collagen, vegetable oil, pectin, cellulose, *Pleurotus eryngii*, *Agaricus bisporus*, and so on (Han & Bertram, 2017; Shin et al., 2020; Zahari et al., 2020; Zhang et al., 2022). There have been claims that *Agaricus bisporus* and *Pleurotus ostreatus* improved the moisture and dietary fibre level of low-fat frankfurters (Ceron-Guevara et al., 2020). *Agaricus bisporus* enriched the rheological properties of meat batter (Nan et al., 2022). Compound fat substitutes, such as vegetable protein and carrageenan, vegetable oil and vegetable fibre, cellulose, and water, improved texture better than single fat substitutes (Zhang et al., 2022). Whereas, little information is available about using *Flammulina velutipes* and soybean oil as fat alternatives in the manufacture of chicken sausage.

Aim of this research

In this context, the effect of *Flammulina velutipes* mushrooms and soybean oil as fat substitutes in the production of chicken sausages was investigated by determining the cooking yield, folding test, pH, color, sensory qualities of chicken sausage. This study can serve as a reference for applying *Flammulina velutipes* and soybean oil in low-fat chicken sausage.

Materials and methods

Fresh chicken breast meat, pork-back fat, *Flammulina velutipes (Fv)* mushroom, sugar, Non-GMO Soybean oil (SO), white pepper powder, salt, sodium polyphosphate were obtained from Century Hualian Supermarket, Hualan Avenue, Xinxiang. Potassium chloride was analytically pure grade.

Raw material treatment. Fresh *Fv* mushroom were cleaned under running water when their roots have been removed. Next, *Fv* mushroom were dried (40 °C for 25 h), ground and sieved through a 40 mesh sieve. Finally, mushroom powder was sealed in polyethylene plastic bags and stored in a desiccator. The extra fat and connective tissue from fresh chicken breasts were removed. Pork skin, lean meat, and connective tissue were removed from pork-back fat. After grinding in a grinder with a 6 mm perforated plate (MM-12, Guangdong, China), chicken breast meat and pork-back fat were loaded separately into vacuum bags and then stored at -40 °C.

Preparation of chicken sausage. Chicken breasts and pork-back fat were thawed in advance. *Fv* mushroom and SO were mixed in a ratio of 1:1.5 in advance. According to the recipe in Table 1, chicken meat, salt, and tripolyphosphate were loaded into a chopper for chopping at 1500rpm for 60s and then stayed for 3min. Next, 1/3 of ice water was added for chopping at 1500rpm for 60s and then stayed for 3min. Pork-back fat, mixture of FV-mushroom and soybean oil (FV-SO), sugar, white pepper, and 1/3 ice water were added for chopping at 1500rpm for 120 s and then stayed for 3min. Finally, the remaining 1/3 of ice water was added for chopping at 3000rpm for 60 s (Nan et al., 2022). To produce chicken sausage, the chicken batter was filled into an impermeable cellulose casing using a stuffer (Model EC-12, Mainca Co., Spain). After manually twisting and tying the sausage links, the sausage was stored at 4 °C for 30 min. The sausages were then cooked for 30 minutes in an 80 °C water bath. Finally, the sausages were chilled in an ice-water bath to a final temperature of less than 10 °C before being stored overnight at 4 °C. Each type of sausage was made in three batches, and three sausages from each batch were chosen for the next analysis.

Method for determination of cooking yield (CY). According to the methods of Juhui C. & Hack-Youn K. (2019) with slight modifications, about 30 g (m_1) of raw chicken was loaded into a centrifuge tube and centrifuged for 10 min at a centrifugal force of 500 g. The tube was then placed in a water bath at 80 °C for 30 min and then removed to obtain cooked chicken batters. The centrifuge tube was quickly immersed in ice water and cooled for 10 min, then the cooked chicken batters was removed from the centrifuge tube, and the surface water and grease were wiped off before measuring the weight of the cooked chicken batters (m_2). The cooking yield was calculated according to the following formula. The measurement was carried out three times for every formulation.

$$CY = \frac{m_1 - m_2}{m_1} \times 100\% \quad (1)$$

Method of folding test. According to the methods of Kamani et al. (2019) with slight modifications, a five-point grading scale was used to assess the folding test results. The sausage was cut into 3 mm thick pieces. To examine how they broke, the slices were carefully folded in half. They were ranked as follows: (1) finger pressure breaks, (2) immediate cracks when folded in half, (3) gradual cracks when folded in half, (4) no cracks visible after folding in half, and (5) no cracks visible after folding twice. The measurement was carried out three times for every formulation.

Table 1
Experimental scheme

Ingredient/g	Fat replacement /%				
	0	25	50	75	100
Chicken	60	60	60	60	60
Pork-back fat / g	20	15	10	5	0
FV + SO	0	2+3	4+6	6+9	8+12
Ice water	20	20	20	20	20
Salt	2	2	2	2	2
Sodium polyphosphate	0.3	0.3	0.3	0.3	0.3
Sugar/g	0.6	0.6	0.6	0.6	0.6
White pepper /g	0.15	0.15	0.15	0.15	0.15

Method for determination of pH. According to the methods of Nan et al. (2021) with slight modifications, in a homogenizer (T25, IKA, Germany), 10 g of chicken sausage and 100 g of 0.1 mol/L potassium chloride solution were blended and homogenized for 1 minute at 8,000 rpm. The homogenates were filtered using Whatman No. 4 filter paper (Whatman, Maidstone, England), and a pH meter (Model 340, Mettler-Toledo GmbH Analytical, Schwerzenbach, Switzerland) was used to test the pH of the filtrate. The measurement was carried out three times for every formulation.

Method for determination of color. According to the methods of Zahari et al. (2020) with slight modifications, chicken sausage was cut into a cylinder of length 2 cm. The color of its center part was measured with CR-400 color meter, and the L* value (brightness), b* value (yellowness) and a* value (redness) were recorded. The measurement was carried out five times for every formulation.

Method of sensory evaluation. According to the methods of Wang et al. (2019) with slight modifications, sensory evaluation of the sausages were done by eight professionally trained college students (four males, four females; ages between 18 and 24) under homogeneous daylight at room temperature. Samples were prepared for each panelist and they were asked about their perceptions on taste, color, texture, flavor, and overall acceptability. This assessment was sensory rated using a nine-point hedonic scale (Extreme like = 9; Very like = 8; Comparatively like = 7; Somewhat like = 6; Neither like nor dislike = 5: Somewhat dislike = 4; Moderately dislike = 3; Very dislike = 2; Extremely dislike = 1).

Statistical analysis. Using IBM SPSS 20.0 statistical software, the one-way ANOVA and means comparison test (Duncan) were performed to analyze the effects of the various formulations. The significance level was set at 5 %. Mean and standard deviation were used to express the data.

Results and discussion

Table 2 shows the effects of different amounts of FV-SO on the CY of chicken sausage. As can be seen from Table 2, compared to CK, the CY of chicken sausage increased significantly when adding FV-SO ($P < 0.05$).

Table 2
CY of chicken sausage

Fat replacement /%	0	25	50	75	100
CY	90.17 ± 0.22e	93.95 ± 0.38d	96.05 ± 0.88c	97.14 ± 0.02b	97.66 ± 0.24a

a–eMeans within a line with different letters are significantly different ($P < 0.05$)

Meanwhile, T_4 had a significantly lower CL ($P < 0.05$). Cooking yield measured the ability of the system to bind water and fat after protein denaturation and aggregation. The CY of the sausages increased significantly ($P < 0.05$) with the increase in the amount of FV-SO, which indicated that the addition of FV-SO significantly increased the ability of the protein gel system to bind water and fat. This may be related to the components of cellulose, hemicellulose and lignin contained in mushrooms that have good oil and water absorption (Kurt & Gençcelep, 2018). Meanwhile, the addition of soybean oil improved the emulsification of myofibrils and formed a better network structure, thus locking in more water and fat.

Folding test. The elasticity of a texture can be assessed through sensory examination utilizing the folding test. Table 3 lists the outcomes of the folding test. There were no significant differences between the four experimental groups containing FV-SO ($P > 0.05$).

Table 3
Result of folding test of chicken sausage

Fat replacement /%	0	25	50	75	100
Folding test value	5 ± 0a	4.67 ± 0.58ab	4.67 ± 0.58ab	4.33 ± 0.58b	4 ± 0b

a–bMeans within a line with different letters are significantly different (P < 0.05)

Folding test values were not significantly different between the samples of 25 % and 50 % and CK (P > 0.05), and were significantly lower in the samples of 75 % and 100 % than in CK (P < 0.05). Folding ability has a close connection with the creation of a protein gel network during the cooking process. Myofibrillar proteins in meat emulsion are responsible for the formation of this network (Zhuang et al., 2017; Wang et al., 2021; Nan et al., 2022). According to Table 3, excess FV-SO inhibited the formation of this protein network and significantly decreased gel strength and folding ability in the final sausage. Overall, the folding test results revealed that replacement of fat by proper amount of FV-SO maintains the gel elasticity in the cooked.

pH. According to Table 4, with the increase in the amount of FV-SO, the pH value of sausage increased significantly(P < 0.05), which was agree with Choe et al. (2018) who discovered that adding winter mushroom powder to meat batter increased its pH.

Table 4
pH of chicken sausage

Fat replacement/%	0	25	50	75	100
pH	6.34 ± 0.07c	6.32 ± 0.08c	6.51 ± 0.05b	6.60 ± 0.02a	6.62 ± 0.01a

a–c Means within a line with different letters are significantly different (P < 0.05)

This could be because proteins in mushroom powder act as a buffer. A higher pH value promoted the development of meat gels, leading in a better gel structure and stronger gel strength. According to the results of the aforementioned analysis, adding FV-SO increased the pH of the sausage, which would be beneficial to improve the gel structure of the sausage.

Color. The color features of meat products are critical for the product's reception by consumers (Vidal et al., 2020). According to Table 5, the addition of FV-SO significantly increased the L* and b* values of the sausages compared to CK, but the L* values gradually decreased and b* values gradually increased as the amount of FV-SO increased.

Table 5
Color of chicken sausage

Fat replacement /%	L*	a*	b*
0	79.03 ± 0.54d	2.06 ± 0.05b	9.04 ± 0.12d
25	81 ± 0.5a	1.6 ± 0.07d	10.94 ± 0.14c
50	79.93 ± 0.16b	1.88 ± 0.11c	12.33 ± 0.34b
75	79.16 ± 0.16c	2.25 ± 0.17b	12.58 ± 0.24b
100	78.42 ± 0.31d	2.66 ± 0.1a	14.38 ± 0.21a

a–d Means within a column with different letters are significantly different (P < 0.05)

The a* values of 25 % and 50 % sausages were significantly lower compared to CK (P < 0.05). This results might be connected to the FV-SO's unique color, which may be linked to the color of soybean oil and the different solubilities of the pigments in mushrooms in water and oil. In conclusion, the addition of FV-SO increased the brightness and yellowness of the sausage, and the low addition of FV-SO decreased the redness of the sausage, which increased when FV-SO completely replaced the fat.

Sensory evaluation. The sensory results of the sausages are presented in Table 6.

Table 6
Sensory parameters of chicken sausage

Fat replacement/%	Taste	Color	Texture	Flavor	Overall acceptability
CK	7.56 ± 0.25b	7.35 ± 0.24a	7.28 ± 0.22b	8.02 ± 0.34b	7.58 ± 0.41a
25 %	8.14 ± 0.22b	6.31 ± 0.31b	7.34 ± 0.22b	8.15 ± 0.45b	7.67 ± 0.32a
50 %	8.92 ± 0.29a	5.24 ± 0.26c	7.83 ± 0.21a	8.34 ± 0.14b	8.21 ± 0.45a
75 %	8.73 ± 0.24a	4.32 ± 0.27d	7.24 ± 0.25b	8.72 ± 0.31ab	7.02 ± 0.21b
100 %	7.59 ± 0.33b	3.89 ± 0.35d	6.67 ± 0.31c	8.89 ± 0.35a	6.51 ± 0.42b

a–c Means within a column with different letters are significantly different (P < 0.05)

The flavors of the sausages with FV-SO all reached a score of 7 or more, indicating that the consumers liked the change in flavor induced by the addition of FV-SO, where the experimental groups of 50 % and 75 % having significantly higher flavor values than CK ($P < 0.05$). The color score values decreased significantly with the addition of FV-SO ($P < 0.05$), where the color scores of 75 % and 100% experimental groups were below 5, indicating that consumers disliked the color changes induced by the addition of FV-SO. 50 % experimental group scored significantly higher than that of CK on the texture ($P < 0.05$), suggesting that the addition of FV-SO in moderation was beneficial to the structural state of the sausages, which is in agreement with the results of the folding test of the present study. The flavor scores of the sausages with FV-SO did not significantly decrease ($P > 0.05$) and were all higher than 8, and the flavor scores of the 100 % experimental group were significantly higher than those of the CK ($P < 0.05$), suggesting that consumers liked the flavor of the sausages with FV-SO. The overall acceptability of the 25 % and 50 % experimental groups was not significantly different from that of the CK ($P > 0.05$). Taken together, the 50 % experimental group had significantly higher flavor and tissue status than CK ($P < 0.05$), while its flavor and overall acceptability were not significantly different from CK ($P > 0.05$), and although its color score was significantly lower than that of CK ($P < 0.05$), it had reached a score of 5 or more, i.e., acceptable to consumers. Therefore, the 50 % experimental group had the highest overall sensory score.

Conclusion

Replacement of fat in chicken sausages with FV-SO significantly increased CY and pH of sausages, which will be beneficial to improve the gel structure of the sausage. Replacement of fat by proper amount of FV-SO maintained the elasticity of the chicken sausage. The addition of FV-SO increased the brightness and yellowness of the sausage, and the low addition of FV-SO decreased the redness of the sausage, which increased when FV-SO completely replaced the fat. Chicken sausage with 50 % fat replacement with FV-SO had the highest sensory score.

Prospects for further research. FV-SO is a promising fat substitute for producing low-fat meat products.

Information on conflict of interest.
There are no any conflicts of interest.

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